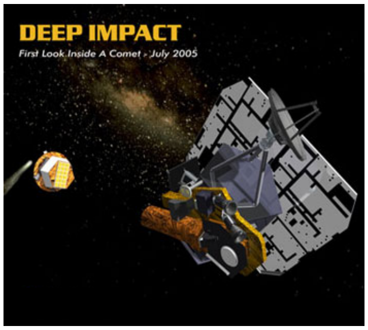


Exploring Comets and Modeling for Mission Success

Activity Purpose and Goals

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator - Enrichment

Purpose:

The purpose of this workshop activity is to give educators information and activities surrounding the basics of comet science. Students get the opportunity to follow the path science has taken throughout history to explore comets. They'll also learn about how we are currently exploring comets and why projects perform modeling exercises on Earth in order to assure mission success in space. Students will understand the physical and chemical properties of comets as we presently understand them.

Goals:

Students will:

- Have the chance to interact with the rest of the class discussing theories on the formation and nature of comets
- Add and eliminate new facts as they incorporate experiment and theory
- Make an ice cream model to visualize comet formation and the technologies used in comet space missions
- Progress from talking about comets to creating models to test their own space designs and comet theories
- Begin with questions and perceptions about comets and progress to building their own solid base of comet knowledge

Educators will:

- Enhance their information about comets in general and the Deep Impact mission in particular
- Integrate historical information into classroom lessons that relate comets to the lives of people
- Employ a model for simulating comet formation and composition using ice cream and another, using a comet model on a stick that gives their students an exercise in evaluation and modification as a common space mission practice
- Encourage communication among students using prompts about comet characteristics and formation
- Use resources that encourage thinking, discussion and writing about comet structure and behavior
- Better understand the mechanics of ice crystal formation and micro-crystal formation in ice cream

Program Description:

Comets have caught the attention of people on Earth from earliest recorded history. Students duplicate the sequential path scientists have taken throughout history to research comets.

- First, they learned by looking up in the sky and through the drawings of others. They guessed about comets.
- Then, they learned by using their knowledge of math, science and eventually using emerging technologies. They began to discover information about the patterns and to understand the elements of comets.
- Now they learn through space exploration. Robotic spacecraft visit comets. Mission teams model cometary environment on Earth to test challenges to their mission design and find solutions.

Students have the opportunity to:

- Elicit #1 - Think how they would initially define a comet based on their current knowledge and possible misconceptions
- Elicit #2 - Model an "ice cream comet" to learn about some of the elements that make up a comet and add to their base of knowledge through new information
- Elicit #3 – Discuss why scientists explore comets and what value they might have to us in the future
- Elicit #4 – Choose the information they might investigate about comets and design the mission they would use
- Elicit #5 – Discuss modeling for the success of a mission and create models for their mission design and comet environment
- Elicit #6 – Research current comet space missions and their technologies

There are many reasons to explore comets both for knowledge and for future resource and protection of the Earth. The underlying goal for this activity is to lead the student from casual observation to an involvement and ownership in comet science.

For the Educator:

The following workshop materials are provided:

For Educators:

- *"Exploring Comets - Activity Purpose and Goals"*
- *"Comet Activity Overview" (activity outline, order of activity)*
- *"Make a Comet Model and Eat it!" – Educator page*
- *"Deep Impact's Comet on a Stick!" – Educator page*
- *"Questions from Past Workshops" – Discussion or student test*

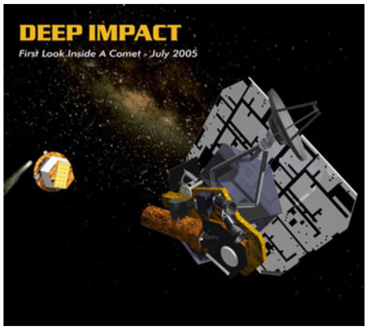
For Students/Educators:

- *"Consider this"* history page
- *"A Comet's Place in the Solar System"*
- *"Exploring Comets" – Student reflection page*
- *"Make a comet model and eat it" Activity*
- *"Make a comet model and eat it" – Student Data Sheet"*
- *"Chemistry of Ice Cream Activity"*
- *"Ten Important Comet Facts"* – Facts about comets
- *"C-O-M-E-T-S – Acrostic"* – Facts about comets
- *"Deep Impact's Comet on a Stick"* – Activity
- *"Paper Comet with a Deep Impact"* – Optional Activity
- *"Comet Models based on the Deep Impact Mission"* – Activity
- *"Deep Impact – Interesting Facts"* – mission background
- Educator/Students – *"Small Bodies Missions"* resource page
- Optional Extension activities from the Stardust comet mission are found at http://stardust.jpl.nasa.gov/classroom/guides.html

You will need to provide:

- Materials for the *"Make a comet and eat it", "Comet on a Stick!",* or other activities you choose from this package
- Household or arts and crafts items to make comet models
- Poster board and pens or enough blackboard space to retain several class discussion lists
- (Optional) Computer to look up mission web sites for research

Questions? – Contact Maura Rountree-Brown Maura.Rountree-Brown@jpl.nasa.gov or
Art Hammon – Pre-College Education Specialist, JPL ahammon@jpl.nasa.gov
The Deep Impact web site: http://deepimpact.jpl.nasa.gov or http://deepimpact.umd.edu



Exploring Comets and Modeling for Mission Success

Activity Overview

Created for the Deep Impact Mission, A NASA Discovery Mission

Maura Rountree-Brown and Art Hammon
Educator - Enrichment

1. FIRST, TELL THEM A LITTLE AND FIND OUT WHAT THEY KNOW.

Past Beliefs – Consider this!
What did people think about comets throughout history and in different cultures? Show a picture of a comet. Use the ***"Consider This"*** page.

Where are comets in the Solar System?
Find a picture of the Solar System and see where the Kuiper Belt and Oort Cloud are in relationship to all the other bodies.
Use the ***"A Comet's Place in the Solar System"*** page

Elicit #1 - What are your ideas about comets?
Use the ***"Exploring Comets"*** page to discuss questions and ideas about the composition and behavior of comets. Record students' answers on a list to re-check later.

2. ADD TO THEIR KNOWLEDGE OF COMETS.

Activity - Make a Comet and Eat it!
Build a representation of a comet with ice cream and candy "debris" using ***"Make a Comet and Eat it!"*** Page. Discuss with students what is taking place as the ice cream forms.
Extension: Stardust's *"Cookin' up a Comet"*, Deep Impact's ***"Chemistry of Ice Cream"***

Explore More - Discussion:
Educator input: Discuss results of student "data" testing. Gather visuals of comets from web sites. Begin with less detailed visuals of comets and then show those with more detail (a picture of a comet, a comet with an ion tail, Shoemaker Levy 9 breaking apart, Giotto and Borrelly views of a comet nucleus). Make a drawing as a group showing components of a comet the students now recognize. It should have a nucleus, coma, two or three tails. Use ***"Ten Important Comet Facts"*** and ***"C-O-M-E-T-S"***.

Elicit #2 - What new ideas do you have about comets, their origin and their composition?
Return to the list of original comet theories and questions the students recorded? Confirm or modify their original ideas. Add new information. Which ideas are still questions within the science community?
Elicit #3 – What ideas do you have about why scientists explore comets? What effect could comets have for and against us in the future?

3. NOW IT'S THEIR TURN TO DESIGN A MISSION

Thinking about modeling for the success of a mission:
Elicit #4 – Pick one thing scientists don't know about comets and design a mission around finding the answer.
As a group or individually, pick one goal for a mission and discuss how it might be met. Have students describe how the mission would work and what kind of real or imagined technology they would use in their design.

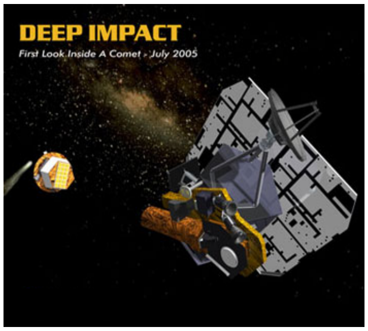
Use the introduction to modeling ***"Deep Impact Comet Models"***. Why do mission teams have to prepare models of cometary environment on Earth in order to assure the success of their mission in space?

Activity: Comet on a Stick!
Make and evaluate the comet on a stick as a model. How would they improve it? How would they make a whole new model? Use ***Comet on a Stick!***
Extension: ***"Paper Comet with a Deep Impact"*** *(option to "Comet on a Stick")* or ***"Comet Models based on the Deep Impact Mission"***, Stardust – *"Aerogello"* For a longer activity, try ***"Excavating Cratering"***.

Elicit #5 – What kind of modeling can you do to test your mission's design and your comet's possible environment?
Have students discuss what they would need to know about cometary environment in order to continue design on their mission. What kind of model can they make here on Earth to test both the mission and the cometary environment?

Elicit #6 – What kinds of comet missions is NASA funding? Use ***Deep Impact – Interesting Facts***. What kinds of technologies are comet missions using? Why? Check out **http://deepimpact.jpl.nasa.gov** **http://stardust.jpl.nasa.gov** **http://www.contour2002.org**
Suggested Stardust activities appear on the Stardust web site.
Use ***"Questions from Past Workshops"*** as discussion or testing tool for students.

Further information about comets- "Maura Rountree-Brown" Maura.Rountree-Brown@jpl.nasa.gov
Classroom concerns: "Art Hammon" Virgil.A.Hammon@jpl.nasa.gov



Consider this!!

Consider the “impact” comets have had throughout history.

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Maura Rountree-Brown and Art Hammon
Student - Enrichment

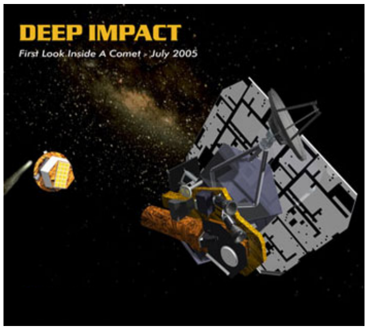
Historical

- Because comets appear suddenly and look different from other celestial bodies, some historical cultures fear them while others revere them.
- Some cultures thought comets predicted coming events. Some Native American cultures used them as count markers to show seasonal change.
- Comets were believed to foretell the death of kings, the demise of great empires and the creation of plagues.
- The appearance of Halley's comet in 1066 was believed to foretell the loss at the Battle of Hastings.
- In 1910, when spectroscopy was new to the world of science, toxic gases were found in Halley's comet. When Earth passed through the comet's tail, some people encouraged the sale of "comet insurance policies" and special medicines for "Comet Fever".

Scientific

- There is the theory that comet impacts on Earth provided both the water and possibly the carbon-based molecules necessary for life.
- About 40,000 tons of dust particles from comets and asteroids fall to Earth every year.
- Comets are both a potential threat and a potential resource. Comets have hit Earth in the past. At some point in the future we will need to know how to draw from their resources and also to protect ourselves against their impacts.
- As the primitive, leftover building blocks of the outer solar system's formation process, comets offer deep within them, clues to the chemical mixture from which the giant planets formed 4.6 billion years ago.

But how do we find out more???



A Comet's Place in the Solar System

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Enrichment

The solar system has four rocky inner planets and four large gas giant outer planets. The planet Pluto is still a mystery. In addition, there are other “small bodies” in the solar system. Comets make up a portion of those small bodies and contain a large percentage of ice since they come from a very cold area. Scientists aren’t sure whether comets are more like snowy dirtballs or dirty snowballs depending on the amount of rocky debris mixed with the icy material. Comets seem to be found in two places: some far beyond the edge of the solar system called the Oort Cloud, and some beyond Neptune in a region called the Kuiper Belt. The Oort Cloud may contain a trillion icy comets. The Kuiper Belt comets replenish the population of short period comets.

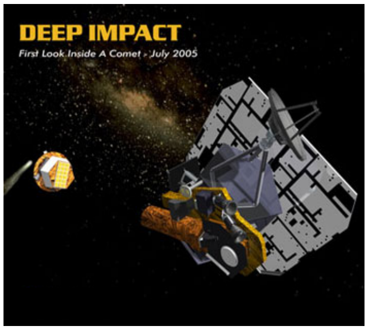
Comets may be an important part of the recipe for making planets and may be material left over from solar system formation. Some comets may have crashed into forming planets adding to their water and rock while other comets escaped to establish their own orbit around the sun.

The orbits of planets line up primarily on one plane like rings on a target. Comet orbits can be different from that of planets. They may arrive in the inner solar system from “above” or “below” the plane of the planets and they travel very far from the Sun. Sometimes, there is a stirring in the Oort Cloud, possibly from the gravity of nearby stars or dark matter bodies that pass through the cloud. That stirring can cause a comet to head from the Oort Cloud into the inner solar system.

The earliest observers to notice comets in the sky could only learn from looking up just like a person looks at a picture of a comet in a book. Later, observers began to notice that comets moved from night to night in the sky. Using what they knew about math, they were able to begin tracking comet orbits. As technologies were developed, scientists could begin observing in a new way to discover the makeup of these icy bodies. Comets may have within them the last pristine clues to the beginning of the formation of the solar system. Some believe that comets may have brought water to earth through impacts.

As gas and dust swirled around the condensed Sun, molecules came together forming compounds. Water and carbon dioxide are two examples of volatiles/ices while olivine and CH-O-N molecules are dust or refractory compounds. Gravity brings the molecules together in clumps that eventually grow to larger and larger cometesimals. Rather than a solid ice cube, comets may be made of many smaller ice crystals with other organic molecules mixed in.

A modeling exercise like making ice cream filled with different foods to represent “debris” can be a good example of the formation of a dirty snowball “comet”.



Exploring Comets

Reflections on comets, missions and modeling

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Reflection

Elicit #1 – What are your ideas about comets? What are comets? Where did they first originate? What components make up a comet? What don't we know about comets?

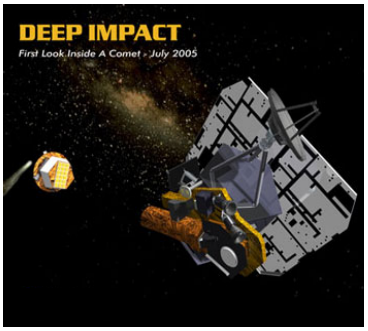
Elicit #2 - After doing some research, what new ideas do you have about comets, their origin and composition? What are the physical parts of a comet? Compare your new information with the list that you built as a class.

Elicit #3 - What ideas do you have about why scientists explore comets? Why do they want to know about them? Why would it make a difference?

Elicit #4 – Pick one of the questions scientists still have about comets and design a mission to find the answer. **How would you investigate a comet? What kind of a mission would you put together? What kind of real or imagined technology would you use?**

Elicit #5 – What kind of "model" would you build to test your design and show your comet's possible environment?

Elicit #6 – Research to see what real comet space missions exist and what kinds of technologies they are using.



Make a Comet Model and Eat It!
Instructor Page

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator - Enrichment

The "Make a Comet and Eat it" activity can be used with a wide age range. Younger students will come away with three important ideas: Comets are cold, they have debris from the early solar system and we still aren't exactly sure what is in them or how they behave. Older students will be able to discuss their own theories about what we will find out about Comet Tempel 1 when we dig deep inside it in July 2005. They can compare their current theories with our results.

The Activity:
"Make a Comet and Eat it!" - The activity
"Make a Comet and Eat it!" - Student Data Sheet - The student work sheet

Background material:
Consider This - This page shows the history of perceptions about comets.
A Comet's Place in the Solar System - A little history about where comets came from
Ten Important Comet Facts - A quick review of comet facts
C-O-M-E-T-S - A comet acrostic. Good for younger students or comet quick fact reference
Deep Impact - Interesting Mission Facts - Some fun facts about our mission
Small Bodies Missions - Learn more about Deep Impact and about other missions to comets and asteroids.

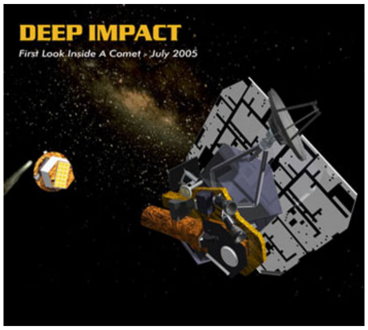
Want to know more about the chemistry of this activity?
The Chemistry of Ice Cream - Learn more about the chemistry of ice cream and how it freezes.
Building a Butterfat Molecule - Gum drops and toothpicks are all you'll need for this one.

National Science Education Standards related to this activity:
Thematic Organizing Standards:
☐ - Personal Social Connection
☐ - Nature and History of Science
☐ - Unifying Concepts and Processes

Curriculum Content Standards:
☐ - Size, Scale and Properties of Solar System Objects
☐ - Energy-Nature of and Properties

Classroom Management:
☐ A. Materials need to be purchased fresh and kept in store-bought containers. Anything that is used to measure, hold or eat with/out of should never have been used for any classroom chemical storage.
☐ B. A mop and sponge is very helpful for desks or floor areas where measuring is done. You may choose to pre-load cream bags and salt bags at home.
☐ C. The ice needs to be either freshly bought or well frozen in storage. The container for transporting and storing the ice should be pre-cooled if possible or very efficient. If the ice has "warmed", it will be difficult to get the milk/cream to solidify.

Questions: Maura Rountree-Brown at Maura.Rountree-Brown@jpl.nasa.gov



Make a Comet Model and Eat It!

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Inquiry

Comets have sometimes been described as dirty snowballs, snowy dirtballs or something in between. But what does that really mean? It means that these dirty snowballs are believed to be a cold mixture of frozen water, dry ice, and other sandy/rocky materials left over from the early formation of our solar system. In this activity, we are going to develop a comet model that you can eat. You'll trade "comets" and pretend to be an instrument on the Deep Impact Spacecraft called a spectrometer. It analyzes the structure and composition of comets by using nine different filters. You will use four of your senses individually to decide what is in the ice cream. Most of the ingredients can be found in your home or can be incorporated there after the activity.

Form small research groups of 2 - 4 students. Survey your class ahead for any allergies (milk, peanuts, etc) that you plan to use. You'll need to gather the following materials for each group:
- One sandwich size re-closable plastic bag per team of 2 - 4
- One Gallon size re-closable plastic bag per team of 2 - 4
- Small cups for eating ice cream - one for each person on the team and one extra cup for ice cream to feel
- Plastic spoons
- Pairs of rubber kitchen gloves or have them use cloths or sweaters (comet gets cold!!)
- Ice (enough to fill a gallon size bag ½ full per team) - or bring in fresh snow from outside.
- Chunky cookies in black or brown, crushed candies (like toffee or peppermint), gummy bears, coconut flakes and peanuts
- Whole milk (2% won't work)
- Sugar
- Vanilla extract
- Evaporated milk
- Salt
- Can opener
- Something to use to crush cookies and other additives

****
To begin: Wash hands! You may choose to use food gloves.

HINT: One person should hold the bag while another pours ingredients into the bag. To cut the activity time, you can pre-mix the milk, evaporated milk, sugar and vanilla to the small bags and pre-measure the salt into the large bags. Make enough sandwich bags of ice cream for each team to have one. Squeeze the air out and seal the sandwich bags carefully each time they are opened to add ingredients.

STEP #1: Mix to the sandwich size bag
One-third cup evaporated milk (or cream)
Two-thirds cup whole milk
5 level spoonfuls of sugar
Less than ¼ tsp of vanilla
Comet connection: Discuss with your class the following ingredients to be added to the ice cream to represent dust (Black/brown cookies in fine and large chunks), rocks (peanuts), carbon dioxide (coconut flakes). Then have the students begin to add ingredients. Make sure they are also adding some ingredients to represent what we might find in a comet. Possibilities are: gummy bears (early organics for life?),

peppermint, toffee or other ingredients you might choose. Remember to choose food that will not dissolve while the ice cream is setting. Now close the bags.

HINT: Squeeze any extra air out of the sandwich bag and close it. **Be sure it cannot leak.** [Turn it upside down to check]

STEP#2

Place the sandwich bag into the bottom of the gallon bag. Put in approximately 10 heaping spoonfuls of salt if you did not pre-load the salt earlier. You can pre-load salt into the bags at home.

STEP #3

Fill the gallon bag (containing sandwich bag) at least 1/3 full of ice.

STEP #4

1. Close the larger bag tightly to remove as much air as possible. Check for leaks.
2. Gently shake and roll the bag while keeping it in constant motion for approximately 6 - 10 minutes or until half the bag has turned to water.
   [SUGGESTION: Rubber gloves, mitts, cloth towels or other thick fabric may be needed to hold the bag because it will get extremely cold. Start with bare hands so students can feel the temperature change].
3. Gently feel the sandwich bag through the icy mixture. When the milk/sugar mixture in the sandwich bag has hardened into soft ice cream, open the gallon bag and remove the sandwich bag containing the ice cream.

STEP #5

Trade your comet with another team so the ingredients are a mystery. Each team should briefly rinse the outside of the sandwich bag they were given with fresh water before opening so that no salt flavor is transferred to the ice cream.

Split the ice cream comet by spooning some into the cups provided, one for each team member. **Make one extra cup and put it aside. Don't eat this one!**

A spectrometer takes different kinds of data through different filters. Pretend that your eyes, hands and taste buds are scientific instruments taking data from your "comet". Take the following "data" and record it on the data sheet:

- Look at the "comet" and see what you can observe **visually.**
- Take the extra cup you laid aside and have your team **feel** the contents with your fingers. Record your data.
- **Smell** the ice cream and see if you find any additional information.
- **Taste** the ice cream and record any final information about what is in it. Compare your results with the team who made the ice cream you tasted.
- Record what you discovered as you watched the elements in the bag become ice cream.
- Share your conclusions about your comet with your class.

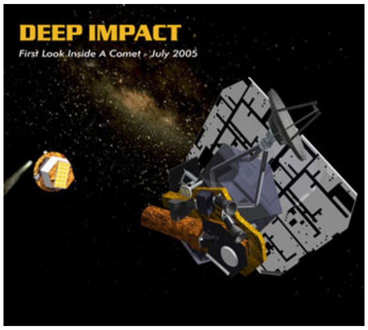
SUGGESTIONS FOR LARGER GROUPS: For a class of 20 (10 groups of 2)

- 3 – 4 cans – 12 fl oz each)
- 1 gallon of milk (you'll have some left over)
- 20 cookies
- ¼ lb of sugar
- 1bag of peanuts and 1 bag of coconut flakes
- ¼ bottle of vanilla or leave this ingredient out
- 10 sandwich size re-closable bags (but best to make a couple extra)
- 10-gallon size re-closable bags
- 2 – 3 containers of table salt (you'll have some left over)

SOME TIPS FOR THE TEACHER:

- If the students toss the bags back and forth or bang them against a surface while freezing the ice cream, they may break.
- Bring dishtowels, cloths or other insulator for hands to guard against discomfort while they are turning their bags over and over.
- Have a mop available for dripping water or do the activity outside.

- Limit the amount of any material students put into their ice cream to one plastic spoonful so supplies last.
- Mark one of your serving cups with sugar and salt measurements to pre-load bags faster. Mix all ingredients in class if you want your students to work on measurements.



Make a Comet Model and Eat It!
Student Research Data Sheet

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Reflection

Throughout history, scientists have used different methods of observation and testing to find out more about comets. First, they used their eyes to look into the sky. Over time, they applied what they knew about math, science and finally technology to further study these icy travelers. Now we have the ability to visit comets. Scientists are always careful to record their observations and data. They use this research to build models to test and confirm their theories about comets. Deep Impact will use a spectrometer with a series of filters to collect different kinds of information about a comet. What can you discover about your ice cream "comet" using your sight, touch, smell and taste "filters" as though you were a spectrometer?

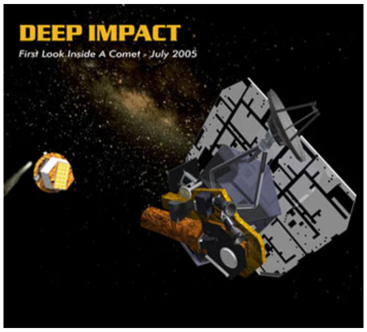
What visual observations do you make about your ice cream comet?

Take the cup you laid aside. Don't taste this one. What are you able to tell by using your fingers to feel the ice cream comet?

What are you able to tell about your comet using only your sense of smell?

What are you able to tell about your comet adding your sense of taste?

What explanations do you draw about the composition of your comet?

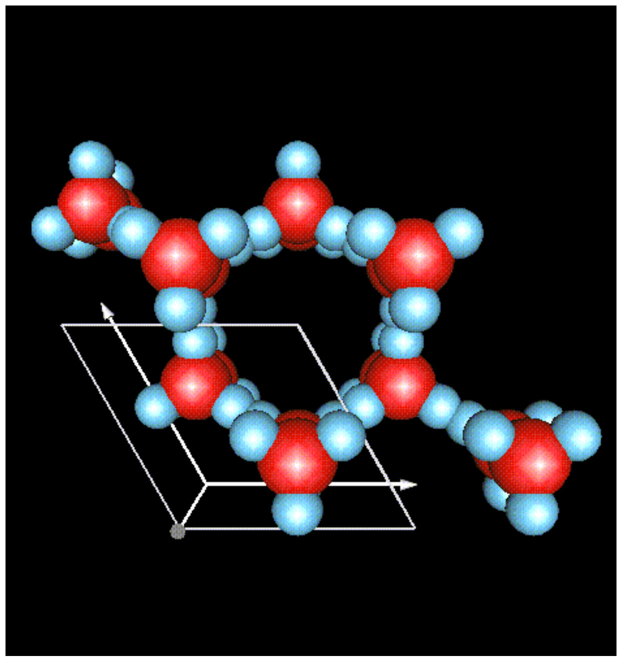


The Chemistry and Thermodynamics of Ice Cream

Created for the Deep Impact Mission, A NASA Discovery Mission

Maura Rountree-Brown and Art Hammon

Educator/Student - Enrichment



"The Reason for the Seasons:" - Snowflake Shapes

The picture above was created at the Institut Laue-Langevin an international research centre and world leader in neutron science and technology. It is based in Grenoble in the South-East of France. It shows an ice crystal. The crystal is made of many molecules of water (H_2O). The atoms are shown by different colors. The darker atoms are oxygen. The lighter atoms are hydrogen. The hydrogen atoms are attached at an angle near 120 degrees. The hydrogen atoms are attracted to each other and form hexagonal rings in all directions.

As ice crystals or snowflakes grow, they expand by attaching new water molecules to each other. Looking at them with a hand lens or microscope tells us about how they join together. The angles are always the same so the designs always have six sides. Whether ice crystals or snowflakes, observing the shape under "atomic microscopes" reveals a shape that is always hexagonal.

If the angle had been different, the shape would have been different. Salt crystals (NaCl) are made of two elements, sodium (Na) and chlorine (Cl) which join at 90 degree angles. Under a hand lens or microscope, the crystals of salt appear as little dice or cubes. The shape of the crystal is determined by the angle of chemical bonding (joining together).

What does “ice” have to do with “ice cream”?

Below is a typical triglyceride butterfat molecule from which ice cream is made. Ice cream is formed when many tiny ice crystals form between the "arms" of the triglyceride butterfat molecule.

O

||

CH_2-O-C-$(CH_2)_7CH=CH(CH_2)_7CH_3$

|

| O

| ||

CH-O-C-

$(CH_2)_7CH=CHCH_2CH=CHCH_2CH=CHCH_2CH_3$

|

| O

| ||

CH_2-0-C-$(CH_2)_7=CHCH_2CH=CH(CH_2)_4CH_3$

Typical molecule of butterfat, a triglyceride, found in ice cream.

Extensions: Chemistry, Crystals and Calories

A. Look at the drawing of the butterfat molecule. The letters stand for chemical elements, joined together in long chains. You can make a “MODEL” of the molecules with gum drops and toothpicks

B. You can make up a code…which element (gumdrop) is which color:
The elements are:
Carbon (C) Color______________
Oxygen (O) Color______________
Hydrogen (H) Color______________

C. Build the molecule with groups assembling a part of a chain. Connect them with toothpicks (chemical bonds…the glue that holds elements together in molecules). . The symbols "=" or "||" mean use two toothpicks. These are called double bonds in chemistry. Then lay them out and connect the whole butterfat molecule on the floor or table.

D. At the same time, make lots of water molecules (H_2O- Oxygen in middle, Hydrogens on each side like a boomerang) and oxygen molecules (O_2). Lay the water molecules between the long chains of the butterfat. Now “freeze” them by connecting three boomerang shaped water molecules together in a hexagon shape, touching the hydrogen atoms together.

E. Why does ice cream make people gain weight? After you eat ice cream, the only way to get rid of it is to “burn” it out of your body. That involves the same idea as burning a match…fuel and oxygen…except this burning is flameless. The ice cream is the fuel and the air you breathe gives you oxygen.

F. “Burn” the ice cream by using the oxygen molecules you made. Oxygen breaks ice cream apart by attacking and breaking the toothpicks and carrying away the Hydrogen and Carbon. Here is the formula:
$C + O_2$ makes one CO_2 (carbon dioxide you breath out)
H + H+O makes one H_2O (water) which you breath out (cold morning breath?)

G. How many oxygens does it take to carry away the butterfat molecule? This is why “Aerobics” is a good idea for weight loss…makes you fill your body with lots of Oxygen to “burn” the butterfat, releasing “heat” measured in calories (a way of measuring energy content).

The Thermodynamics and Chemistry of Ice Cream
(Where is the heat going and what happens to ice cream after you eat it?)

What is going on in the bags?

A. The inside of the ice is very cold, -10^o to $–20^o$ F. But when you hold an ice cube, the exterior, in contact with air and your hand is $+32^o$ F, cold water. Clean, pure water cannot be a liquid below $+32^o$ F. It becomes ice.

B. Salt Mysteries- The mixture of salt and water can be liquid below $+32^o$ F. It can be a liquid down to $–20^o$ F. So adding salt does not “melt ice”. It makes a mixture of water and salt that has a low temperature… “Salt gives water permission to freeze at a lower temperature”.

C. The very cold salt water surrounds the baggie with the milk (which is 30% water) and “steals” heat from the milk. The temperature of the milk becomes so cold that the water in the milk begins to form tiny ice crystals. The butterfat does not form crystals. The shaking keeps the milk from forming one big ice cube.

D. What is a comet - ice cube or ice cream? Deep Impact will help us find out. The data from Deep Impact will tell us a little about how the comet formed…blob of water or snowball of crystals that came together.

Art Hammon, Pre-college Education Specialist, JPL
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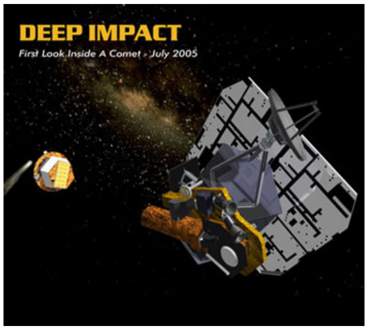


Ten Important Comet Facts

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Enrichment

1. Comets are in orbit around the Sun as are our planets.

2. Comets are composed of ices, dust and rocky debris carried from the early formation of the solar system 4.5 billion years ago.

3. Comets are remnants from the cold, outer regions of the solar nebula. They are generally thought to come from two areas – the Oort Cloud and the Kuiper Belt. Both of these are areas where materials left over from the formation of our solar system have condensed into icy objects. Both regions extend beyond the orbits of Neptune and Pluto but are still part of our solar system and much closer to us than the closest star.

4. Comet orbits are elliptical. It brings them close to the sun and takes them far away.

5. Short period comets orbit the Sun every 20 years or less. Long period comets orbit the Sun every 200 years or longer. Those comets with orbits in between are called Halley-type comets.

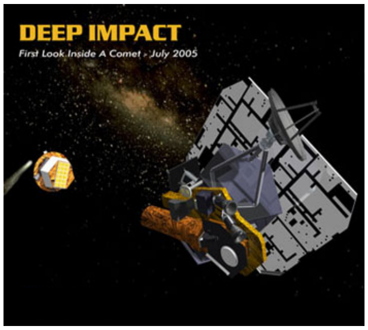
6.Comets have three parts: the nucleus, the coma and the tails. The nucleus is the solid center component made of ice, gas and rocky debris. The coma is the gas and dust atmosphere around the nucleus, which results when heat from the Sun warms the surface of the nucleus so that gas and dust spew forth in all directions and are driven from the comet’s surface. The tails are formed when energy from the Sun turns the coma so that it flows around the nucleus and forms a fanned out tail behind it extending millions of miles through space.

7. We see a comet’s coma and tail because sunlight reflects off the dust (in the coma and dust tail) and because the energy from the Sun excites some molecules so that they glow and form a bluish tail called an ion tail and a yellow one made of neutral sodium ions.

8.Scientists have seen comets range in size from less than 1 km diameter to as much as 300 km, although the 300km (called Chiron) does not travel into the inner solar system.

9. We know a comet could impact Earth and that it is important to understand the nature of comets so we can design better methods to protect ourselves from them should one be on a collision path with Earth.

10. A comet nucleus has a dark, sometimes mottled surface but we don’t if it has an outer crust or if it is layered inside. We don’t really know what comets are like beneath their surface.



The Deep Impact Comet Acrostic

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Enrichment

C
ARE COLD AND ICY
HAVE COMA
DO THEY HAVE A CRUST?

O
OUTGAS ICE AND DUST
COME FROM THE OORT CLOUD OR KUIPER BELT

M
MIDDLE CALLED A NUCLEUS
MILLIONS OF MILES OF TAIL

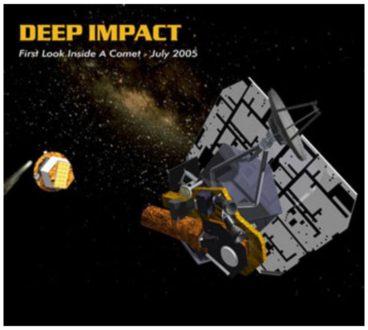
E
FROM THE EARLY SOLAR SYSTEM
HAVE ELLIPTICAL ORBITS

T
THREE TAILS - DUST, ION AND NEUTRAL SODIUM

S
THE SUN HEATS COMETS TO CAUSE OUTGASSING, REFLECTION OF DUST, MOVING THE COMA BACK TO FORM A TAIL. COMETS ARE SNOWY DIRTBALLS OR DIRTY SNOWBALLS - WHICH ONE??

ALSO: The appearance of the nucleus is very dark and sometimes mottled because the out gassed rocky material clings to the surface. They hold important clues to the formation of the solar system and could potentially offer natural resources for us if we ever live in space. A comet that takes 200 years or more to pass around the Sun is a ***long period comet*** while ***short period comets*** come more often, every 20 years or less. Comets with orbit periods in between are called ***Halley-type comets***. Want to know more?

Check out the Deep Impact mission to a comet at:
http://deepimpact.jpl.nasa.gov or http://deepimpact.umd.edu
Find out about more NASA comet missions at:
http://stardust.jpl.nasa.gov



Deep Impact's Comet on a Stick!
Educator Page

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator - Enrichment

The "Comet on a Stick" activity can be used with a wide age range. All students will see that modeling is continuous on a NASA mission as is evaluation of those models. Younger students will learn the basic characteristics of a comet. Older students will practice evaluation and improvement of the comet model shown. The importance of this activity is not the initial model or its exercise, but the fact that it will put students in the position of emulating a process scientists and engineers follow on all missions.

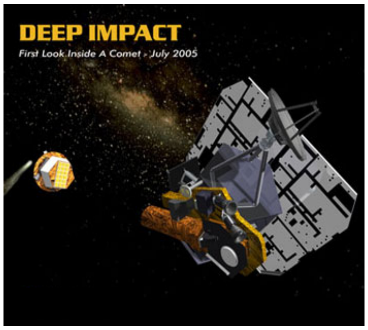
The activity:
"Comet on a Stick" - The activity
"The Deep Impact Paper Comet" - A less expensive version of the "Comet on a Stick for wider use"
Supplies are shown on each activity. Gather household and art supplies so that students can improve or build new models.

Background materials for this activity:
Consider This - This page shows the history of perceptions about comets.
A Comet's Place in the Solar System - A little history about where comets came from
Ten Important Comet Facts - A quick review of comet facts
C-O-M-E-T-S - A comet acrostic. Good for younger students or comet quick fact reference
Deep Impact - Interesting Mission Facts - Some fun facts about the Deep Impact mission
Small Bodies Missions - Learn more about Deep Impact and about other missions to comets and asteroids.

National Science Education Standards related to this activity:
Science as Inquiry:
☐ - Identify questions that can be answered through scientific investigations
☐ - Think critically and logically to make the relationships between evidence explanations
☐ - Develop descriptions, explanations, predictions and models using evidence
☐ - Recognize and analyze alternative explanations and predictions

Tips for materials to improve or build comet models:
☐ - Find fruits and vegetables that might look like a comet nucleus.
☐ - Get different "surface" coverings like chocolate cake mix or icing, chocolate shell (you'll need
☐ to freeze the object you cover)
☐ - Paper or streamer of different kinds
☐ - Paints or other coloring solutions
☐ - Any kind of textured covering that you think would be useful
☐ - Netting or other shear fabrics
☐ - Bulk cushion stuffing fiber or cotton balls
☐ - Tin foil
☐ - See what else you can come up with

Questions: Maura Rountree-Brown at Maura.Rountree-Brown@jpl.nasa.gov



Deep Impact Comet Modeling

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Enrichment

Modeling is an important part of any space mission and begins earlier than most people think. Before any piece of hardware is built or software is designed, in fact, before anyone begins to make calculations for the size and shape of the spacecraft, intensive research must be done and certain questions must be asked.

☐ - What do we want to find out?
☐ - Where should we go in space to find this information?
☐ - In the case of the Deep Impact mission, what do we know about Comet
☐ Tempel 1?

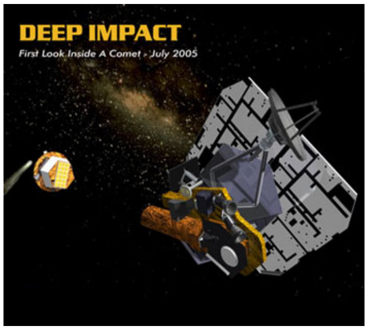
Obviously, it isn't possible to visit Tempel 1 to get all the information we need in order to design a mission so scientists and engineers perform exercises to "model" our comet. They ask themselves questions like:

☐ - What other comets do we have information on?
☐ - What has that information told us?
☐ - If we build a model for a comet we know better, will it tell us what we need to
☐ know about the one we will visit?

The Deep Impact mission has used Giotto's images of Halley's comet as well as the more recently collected images of DS1's views of the comet Borrelly. Using what we know about those comets, and combining that information with images of Comet Tempel 1 taken from Earth, the Deep Impact team has created models for researching the following challenges:

☐ - How fast is Tempel 1 rotating and is it slow enough to allow us to see the crater
☐ we make?
☐ - When sunlight falls unevenly on the comet, can we design software that will help
☐ our impactor find the best lit area to target?
☐ - Based on what we know about cometary dust environments, will our impactor and
☐ spacecraft arrive safely to impact? How large a dust particle can the twin spacecraft
☐ survive before the images they are collecting are blurred or the spacecraft
☐ themselves are damaged?

Questions for your students: If you were building a model of a comet out of odds and ends ☐ around the house, what fact about a comet would you choose to show and what materials would you find to build it? If you were designing a mission, how would you use your comet model to test some of your challenges and bring them to solutions?



"Deep Impact Comet on a Stick"

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Inquiry

Purpose:

Develop a model of a comet and use the same thought processes as a science and engineering team do to design and build missions. Use it to test your theories about comets and then evaluate the strengths and weaknesses of your comet model. The importance of the activity is not the initial model, but the model your students improve or design and their evaluation of the initial model.

Project:

The **Deep Impact** mission will launch in 2004 and encounter Comet Tempel 1 on July 4th of 2005. The **Stardust** mission is in space right now and headed toward Comet Wild (pronounced Vilt) 2. Before these missions launch, scientists and engineers use modeling to research and test some of their theories about comets. They also use modeling to find solutions to some of their mission challenges. Modeling takes place throughout the life of a mission as challenges arise. You can try modeling by making a "Comet on a Stick". Use it to test the influence of the Sun on these small bodies. Discuss as a class some theories about comets. Then try to communicate them with the stick comet. This is a good model for some of the attributes of a comet. For others, it is not. Can you figure out which are the strengths and weaknesses for this model? Can you improve the stick comet model? Can you design your own model to communicate what you know or need to know if you are going to design a mission to a comet? If you need to know more about comets, visit http://deepimpact.jpl.nasa.gov and http://stardust.jpl.nasa.gov to learn more about the Deep Impact Stardust missions.

Before you start:

As a class, discuss what you know about comets. Build one list. Add to that list the things you wonder about comets or don't know. Now you want to build a model to study one question: If you have to send a spacecraft to a comet, what will you need to consider about the way the Sun affects a comet? Now, build your "Comet on a Stick".

Materials:

One 2" styrofoam or other ball	Two 1 – 2 ft lengths of mylar gift strips
One 5" strip of tape	One wooden skewer (shish kabob type)
An electric hairdryer/electrical power available	One marker pen

You or your students gather household or art supplies for students to use to design their own comet models.

Directions:

1. Make a tiny hole in the ball so it can be mounted on the skewer (the fit of the skewer should be tight). Mount the ball on the skewer.
2. Place the mylar strips on top of the ball so the two pieces cross each other in an "X" and the lengths of all sides of the strips hang down evenly. You can also use light ribbon.
3. Attach the strips to the ball with the 5" strip of tape or narrow masking tape wrapped over the strips and around the circumference of the ball.
4. With a marker pen, assign a "front" for your comet and represent it with the letter "H" for head. On the opposite side, mark the letter "T" for tail of the comet.

Here's what you do:

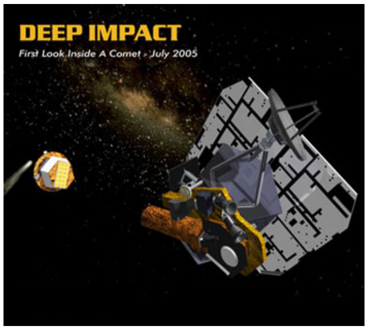
Use a hairdryer to simulate a portion of the Sun's solar energy as it meets the comet. The heat from the Sun causes gas, ice, particles and rocky debris of various sizes to burst from the comet (called coma) and the solar wind causes these substances to form a "tail" behind the comet. Have someone be the "Sun" and stand in place with the hairdryer. The hairdryer simulates the solar wind causing the comet tail (mylar strips) to form and trail behind the comet. Aim the hairdryer at the comet as it approaches and as it moves away. The "Sun" will have to turn in place to keep the "solar wind" flowing to the comet. You hold the comet by the stick and walk in an elliptical orbit around the Sun. As the comet gets closer to the Sun, the solar heating and solar wind affects the comet so that the tail forms and so that it stays in opposition to the Sun. As it travels away, the lost solar heating of the Sun causes the tail to diminish.

Questions: Use the materials you gathered to have students improve or build new models.

1. How does this model succeed in showing the influence of the Sun on a comet?
2. How is this model unsuccessful at showing the proper influence of the Sun?
3. What other elements of a comet can be seen using this model?
4. Which elements of a comet are not well shown by this model?
5. Can you improve the model by changing it or making an entirely new model?
6. The Stardust mission takes a comet sample by flying near the front of Comet Wild 2 instead of the trailing tail. Why? Can you model the reason for their decision?
7. The Deep Impact mission makes a crater in the nucleus of Comet Tempel 1 with a copper projectile. A sister spacecraft nearby takes optical and spectrometer data during the encounter and for 14 minutes after impact. What do they need to consider about a comet in order to successfully gather their data?
8. Form teams and choose three facts about comets you would like to show through modeling. Make a new model or improve your ping-pong comet.
9. As a team decide what kind of comet mission you would design. Take one of the challenges you will face and try to create a model that will help you work the challenge to a solution.

Tips for the Teacher:

1. A hairdryer only sends "wind" from one side while the Sun would be sending out solar wind from all sides.
2. This model does form a tail with the solar wind but it fails to show that the material that outgases from the comet mostly shoots forward. This is why we see the front of the comet glow but do not directly see the nucleus of the comet which is hidden further back inside the comet's coma.
3. The Stardust mission will not take its sample from the tail behind the comet because there is a much higher concentration (density) of material on the sunward side where it originates. By the time it blows back into the tail, it is very spread out. Similarly, the Deep Impact observing spacecraft must maintain a path beneath the comet, which passes overhead. This helps the spacecraft to avoid coma debris from the comet tail and safely transfer its images and other data to Earth through the Deep Space Network antennas.
4. This model does not show that the tail of a comet appears curved because in space we see a "history of the tail". At any point in time, particles move directly away from the Sun (as in this model). Over time, as the comet curves around the Sun on its orbit path, the particles leave a tail that is curved (not shown in this model).
5. As the comet moves away from the Sun, the model tail droops. In space, the particles and debris continue to be swept away from the nucleus, but the production rate of debris decreases.
6. Comets are not white since the rock and debris being outgassed clings to the surface of the comet in a crust that is blacker than toner for a copy machine. Comets also appear in different irregular shapes and are not round "balls". They are shaped more like potatoes. Scientists are not sure how rough or smooth the surface of a comet might be and will get that information from the missions currently planned by NASA.
7. Comets have three tails: the largest is the dust tail produced by radiation light pressure from the Sun. The ion tail, produced by "solar wind" and a neutral sodium tail produced by solar wind.



Paper Comet Model with a Deep Impact

An option to the "Comet on a Stick"

Created for the Deep Impact Mission, A NASA Discovery Mission

Maura Rountree-Brown and Art Hammon

Student - Inquiry

Purpose:

Develop a model of a comet and use the same thought processes as a science and engineering team do to design and build a mission. Use it to test your theories about comets and then evaluate the strengths and weaknesses of your comet model. The Paper Comet is an option to the "Comet on a Stick". The value of this activity is not in the original model but in the evaluation and changes your students make to it.

Project:

The **Deep Impact** mission will launch in 2004 and encounter Comet Tempel 1 on July 4th of 2005. The **Stardust** mission is in space right now and headed toward Comet Wild (pronounced Vilt) 2. Before these missions launch, scientists and engineers use modeling to research and test some of their theories about comets. They also use modeling to find solutions to some of their mission challenges. Modeling can and often does take place throughout the life of a mission. You can try modeling by making a paper comet and considering the influence of the Sun on these small bodies. Discuss as a class some theories about comets. Then try to communicate them with the paper comet. This is a good model for some of the attributes of a comet. For others, it is not. Can you figure out which are the strengths and weaknesses for this model? Can you improve the paper model? Can you design your own model to communicate what you know or need to know if you are going to design a mission to a comet? If you need to know more about comets, visit http://deepimpact.jpl.nasa.gov and http://stardust.jpl.nasa.gov to learn more about the Deep Impact and Stardust missions.

Before you start:

As a class, discuss what you know about comets. Build one list. Add to that list the things you wonder about comets or don't know. Now you want to build a model to study one question: If you have to send a spacecraft to a comet, what will you need to consider about the way the Sun affects a comet? Now, build your paper comet.

Materials:

One 8 ½ X 11 sheet of paper
One 2" strip of tape
An electric hairdryer/electrical power available
Two 1 – 2 ft lengths of mylar gift strips
One non-bending drinking straw
One marker pen
You or your students gather household or art supplies so that the students can improve/build new models.

Directions:

1. Cut or tear the corners of your sheet of paper to within 3 inches of the center of the page.
2. Place the mylar strips evenly one across each paper slit so they form an X on the paper.
3. Crumple the paper into the shape you think best represents a comet and make sure that your strips of mylar stay to the outside of your paper and can fly like streamers.
4. Decide a "front" for your comet and represent it with the letter "H" for head. On the opposite side, mark the letter "T" for tail of the comet.

Here's what you do:

Use a hairdryer to simulate a portion of the Sun's solar wind as it meets the comet. The heat from the Sun causes gas, ice, particles and rocky debris of various sizes to burst from the comet (called coma) and the solar wind causes these substances to form a "tail" behind the comet. Have someone be the "Sun" and stand in place with the hairdryer. The hairdryer simulates the solar wind causing the comet tail (mylar) to form and trail behind the comet. Aim the hairdryer at the comet as it approaches and as it moves away. The "Sun" will have to turn in place to keep the "solar wind" flowing to the comet. You hold the comet by the straw and walk in an elliptical orbit around the Sun. As the comet gets closer to the Sun, the solar heating and solar wind affects the comet so that the tail forms and so that it stays in opposition to the Sun. As it travels away, the lost solar heating of the Sun causes the tail to diminish.

Questions: Use the materials you gathered to have the students improve or build new models.

1. How does this model succeed in showing the influence of the Sun on a comet?
2. How is this model unsuccessful at showing the proper influence of the Sun?
3. What other elements of a comet can be seen using this model?
4. Which elements of a comet are not well shown by this model?
5. Can you improve the model by changing it or making an entirely new model?
6. The Stardust mission takes a comet sample by flying near the front of Comet Wild 2 instead of the trailing tail. Why? Can you model the reason for their decision?
7. The Deep Impact mission makes a crater in the nucleus of Comet Tempel 1 with a copper projectile. A sister spacecraft nearby takes optical and spectrometer data during the encounter and for 14 minutes after impact. What do they need to consider about a comet in order to successfully gather their data?
8. Form teams and choose three facts about comets you would like to show through modeling. Make a new model or improve your paper comet.
9. As a team, decide what kind of comet model you would design. Take one of the challenges you will face and create a model that will help you find a solution to the challenge.

Tips for the Teacher:

1. A hairdryer only sends "wind" from one side while the Sun would be sending out solar wind from all sides.
2. This model does form a tail with the solar wind but it fails to show that the material that outgases from the comet also shoots forward. This is why we see the front of the comet glow but do not directly see the nucleus of the comet which is hidden further back inside the comet's coma.
3. The Stardust mission will not take its sample from the tail behind the comet because there is a much higher concentration (density) of material on the sunward side where it originates. By the time it blows back into the tail, it is very spread out. Similarly, the Deep Impact mission must avoid coma debris from the tail until the data is safely transferred from the sister spacecraft to Earth through the Deep Space Network antennas.
4. This model does not show that the tail of a comet appears curved because in space we see a "history of the tail". At any point in time, particles move directly away from the Sun (as in this model). Over time, as the comet curves around the Sun on its orbit path, the particles leave a tail that is curved (not shown in this model).
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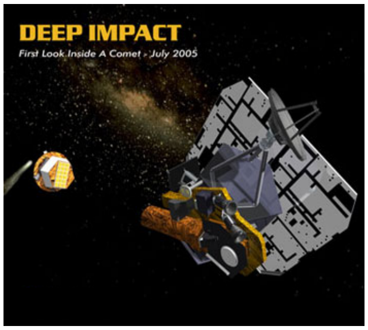
7. Comets have three tails: the largest is the dust tail produced by radiation light pressure from the Sun. The ion tail, produced by solar wind, and the neutral sodium tail produced by solar wind.

Questions? Contact: Maura.Rountree-Brown@jpl.nasa.gov



Comet Models
Based on the Deep Impact Mission

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Inquiry

Here are some comet models you can try to build. Then design your own model. You can also use these models to explore some of the facts and concepts about comet science.

Comets have a dark surface we can't see through. From what is it made?

Make several ice cream balls or use baking potatoes and cover them with different materials:

- Is it a hard crust? – Use chocolate shell. (hardens into a layer)
- Is it a slushy crust? – Use chocolate syrup
- Is it powdery – Use cocoa powder or cake mix
- Is it rough and thick – Use broken cookies

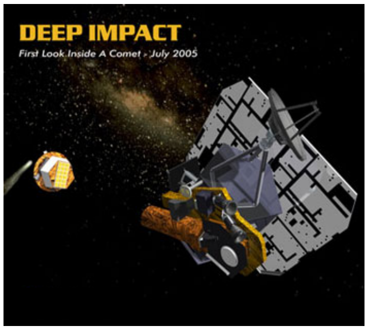
Cover the surface of your "comet" so that the inner contents can't be observed. (The Deep Impact Mission will visually observe how the impact is made to the surface of the crust to learn more about its makeup.) Try to have another team design an experiment to see what is beneath the surface of your comet? Which kind of surface do you think we will find on a comet and why?

What do you think we will find beneath the surface of a comet?

Look for a candy bar that you believe might show what it is like under the surface of a comet. Is it a dark or light? Is it smooth or full of "debris" – peanuts, candy etc? Are there layers beneath the surface or not, and is it a delicate or sturdy in formation? Why do you think you have picked a good model?

How will you build and evaluate your own model?

Have the class bring materials from home and have teams decide on a mission design, comet theory or comet question they would like to communicate. Have them design a model to communicate their question about a comet. Have them build it and design a test to try to confirm their theory or answer their question. Was it a good model and can they improve it? If there is time, work on an improved designed based on evaluation of the first model.



Deep Impact
Interesting Comet Facts

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Enrichment

1. The term “comet” comes from the Greek “kometes” meaning long hair, referring to the tail.

2. The flyby spacecraft is about the size of a Volkswagen Bug.

3. The impactor is about 3 X 3 feet, about the size of a desk and weighs 370 Kg (820 lbs).

4. The entire combined spacecraft weighs about 1 ton.

5. The closing speed of the comet to the impactor is 10 times faster than a speeding bullet.

6. The size of the crater is expected to range in diameter from that of a house to that of a football field and to be several stories deep.

7. The ejecta curtain coming out of the crater might look like what you get when you throw a rock into a can of paint (funnel shaped spray).

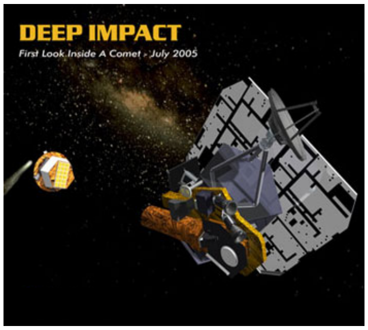
8. If you view the impact of Comet Tempel 1 from earth with a large telescope it might look like a bright flash followed by a glowing stream. It would take a couple of minutes after the flash for the "stream" to separate from the center of the comet.

9. The impact will not knock the comet out of its orbit because the force of the collision between the impactor and the comet is less than a moving truck hitting a pebble. It does not affect speed or direction to any noticeable degree.

10. It takes 7 1/2 minutes for the flyby spacecraft signal to reach earth. Once the mission is within its last hour, there is no time for the team on Earth to communicate effectively with the twin spacecraft. That is the reason auto navigation systems are being built into the flight plan.

11. The communication time between the flyby spacecraft and the impactor takes less than one second.

12. The impactor does not actually speed toward the comet. The impactor aims to place itself in the path of the approaching comet and it is actually the comet that hits the impactor and vaporizes it. The flyby spacecraft has moved away and below the comet path to observe the impact. After the impact, the comet passes over the top of the observing flyby spacecraft and continues on its orbit around the Sun.



Deep Impact Questions

Created for the Deep Impact Mission, A NASA Discovery Mission

Maura Rountree-Brown and Art Hammon

Student - Inquiry

These are the questions that Elicit #1 "What are your ideas about comets?" has brought in past educator workshops. Some of the questions were consistent between both workshops. You can use these questions for discussion or as an evaluation tool with your students.

- Where do comets come from?
- What are comets made of?
- How do they get from their origin to near Earth?
- What is inside them?
- Where are they now?
- How do you tell the difference between a comet and a shooting star?
- How many are there?
- What is the tail made of?
- Do they all travel the same direction?
- What makes them fly?
- Are they hot and burning?
- Is the tail dangerous?
- What is the life span for a comet?
- Is a comet a ball of gas?
- Is it ice?
- Is it a rock?
- Is it a ball of fire?
- Is it like a shooting star?
- What activates comets?
- Why was Halley's Comet so popular?
- Can they be re-routed?
- How close do they come to Earth?
- Do they have a head and a tail?
- Are they from deep in outer space?
- Are they from the black hole?
- What is "periodic"?
- What keeps them going? Do they have something like a jetpack?
- Why are new ones discovered?
- How do you distinguish one comet from another?

Small Bodies Missions

Deep Impact joins a suite of missions that will travel to other comets and asteroids and learn more about our solar system.

Comet Missions

STARDUST

Launch Date: February 7, 1999
Destination: Comet Wild 2
Encounter: January 2004
Sample Return: 2006
Objective: Collect comet dust and interstellar dust particles for return to earth
Description: This will be the first mission to collect samples from a comet and return them to earth. Stardust will make three loops around the sun before its closest approach to the comet. Samples will be captured in a special material called aerogel and the collector will retract into a sample return capsule. The capsule will be returned to earth during a soft landing at the U.S. Air Force's Utah Test and Training Range.
Web site: http://stardust.jpl.nasa.gov

CONTOUR

Launch Date: July 3, 2002
Contact Lost: August 15, 2002
(The following are the original scientific objectives for the CONTOUR mission.)
Destination: Comet Encke, Comet Schwassmann-Wachmann 3
Encounter: November 2003, June 2006
Objective: Encounter and study at least two comets by taking high-resolution pictures
Description: The Comet Nucleus Tour (CONTOUR) will encounter at least two comets during their visit to the inner solar system. The spacecraft will encounter each comet during its peak of activity close to the sun and take high-resolution pictures. They will then perform analyses of their composition. They will also determine the comet's precise orbit. Timing for the mission will also allow for ground-based observations. There may be an extended mission to fly by Comet d'Arrest in 2008.
Web site: http://www.contour2002.org

ROSETTA

Launch Date: January 2003
Destination: Comet Wirtanen
Encounter: November 2011
Objective: Travel to and land upon the surface of the comet to study its nucleus
Description: The Rosetta spacecraft will perform remote study of the nucleus and study its surface using a landed instrument package. Prior to arrival at Comet Wirtanen, the Rosetta spacecraft will fly by asteroid 4979 Otawara in July 2006 and asteroid 140 Siwa in July 2008. This mission is designed and managed by the European Space Agency (ESA).
Web site: http://sci.esa.int/rosetta

DEEP IMPACT
Launch Date: January 2004
Destination: Comet Tempel 1
Encounter: July 4, 2005
Objective: Impact the surface of a comet with a 370 kg impactor creating a crater that exposes fresh material from the interior, study crater formation and composition of the interior.
Description: Deep Impact will be the first mission to look beneath the surface of a comet by making a crater that will expose fresh material from its interior and observing its formation and chemistry of materials beneath. The dual spacecraft mission will collect images and spectra of the impact and its aftermath from the impactor, the flyby spacecraft and from ground and space based observatories. The flyby spacecraft will have approximately 14 minutes to observe the crater before the comet passes over it. After turning, the spacecraft will observe the comet for another 24 hours as the spacecraft continues its solar-centered orbit.
Web site: http://www.deepimpact.umd.edu

Asteroid Missions

NEAR SHOEMAKER
Launch Date: February 17, 1996
Destination: Asteroid Eros
Encounter: February 14, 2000
Objective: Orbit asteroid Eros for a period of one year
Description: The NEAR spacecraft entered the orbit around Eros in February of 2000 to determine its structure, geology, mass, composition, gravity and magnetic field. Having successfully completed its mission objectives, the project team took on an extended objective to land the spacecraft on the surface of Eros. The Near spacecraft touched down on February 12, 2001 transmitting 69 close-up images as it descended.
Web site: http://near.jhuapl.edu

DEEP SPACE 1
Launch Date: October 24, 1998
Destination: Comet Braille, Comet 19P/Borelly
Encounter: July 1999, September 2001
Objective: Test new technologies in space to fly by a comet
Description: The thorough testing of new technologies meant flying them on missions with a strong resemblance to missions of the future. The DS1 mission has successfully tested 12 new technologies in space including:

- An ion drive rocket engine
- A new solar panel design that concentrates sunlight
- An autonomous navigation system that guides the spacecraft using established positions of asteroids

On its way to Comet Borelly, the DS1 spacecraft flew past asteroid (9969) Braille in July 1999.
Web site: http://nmp.jpl.nasa.gov/ds1

MUSES-C

Launch Date: December 2002 or May 2003
Destination: asteroid 1998 SF36
Encounter: September 2005
Sample Return: June 2007
Objective: Collect up to three asteroid surface samples for return to Earth
Description: The Muses-C will arrive at asteroid 1998 SF36 and collect up to three surface samples before returning them to earth. The Japanese Institute for Space and Astronautical Sciences (ISAS) is managing the mission with some technical assistance provided by NASA.
Web site: http://www.isas.ac.jp/e/enterp/missions/muses-c/index.html

DAWN

Launch Date: May 27, 2006
Destination: Vesta & Ceres
Encounter: Vesta July 2010 - July 2011, Ceres Aug 2014 - July 2015
Objective: Orbit two of the largest asteroids in the asteroid belt
Description: Dawn will orbit Ceres and Vesta, two of the largest asteroids in the asteroid belt, for 11 months each in order to characterize the conditions and processes of the solar system's earliest epoch. The top level question that the mission addresses is the role of size and water in determining the evolution of the planets. Ceres and Vesta are the right two bodies with which to address this question, as they are the most massive of the protoplanets, baby planets whose growth was interrupted by the formation of Jupiter.
Web site: http://www-ssc.igpp.ucla.edu/dawn/